Monitoring of Peach Harvest Workers Exposed to Azinphosmethyl Residues in Sutter County, California, 1991

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SUMMARY

Peach harvest workers were evaluated for exposure to azinphosmethyl residues by measuring foliar residues, urinary alkyl phosphate metabolites, plasma and erythrocyte (RBC) cholinesterase (ChE), and dermal residues using clothing and skin washes. Workers entered orchards 51 days after application and worked in treated fields for ten of the next 17 days. Dislodgeable foliar residues ranged from 0.82-1.72 µg/cm^2 and did not change significantly over the study period. Combined mean dermal exposure for the three consecutive monitoring days was 32 mg and ranged from 17.9-60.5 mg. Overall mean excretion levels for the five monitoring days were 1.7 mg dimethylphosphate and 1.9 mg dimethlythiophosphate. There was no significant difference in plasma ChE between the exposed harvesters and nonexposed sorters. The exposed group had significantly lower RBC ChE values than the controls for two post-exposure blood draws by three testing methods while no significant difference was found for the pre-exposure blood draw. The RBC ChE values for the post-exposure blood samples for the exposed decreased significantly about 10-20% over the three week exposure period, but increased or remained constant for the nonexposed. Urinary metabolite excretion was shown to increase with continuous exposure and was inversely correlated with both RBC and plasma ChE, but was not correlated with dermal exposure measurements. High correlations were generally observed between RBC ChE measurements taken in the field using a new spectrophotometric kit and laboratory ChE measurements.

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INTRODUCTION

This study was conducted to evaluate field worker exposure to azinphosmethyl during peach harvest. Monitoring was conducted using dislodgeable foliar residues (DFR), dermal dosimeters, blood cholinesterase (ChE) levels and urinary metabolites. Harvester exposures have historically been difficult to measure since dermal exposure monitoring provides only an index of exposure and although it is typically the primary exposure route, it may not reflect the important sources of exposure. The traditional method of using dermal dosimeters, whether whole body clothing or gauze pads, gives data that is an inaccurate predictor of absorbed dose in humans (Ritter and Franklin; 1989; Maddy et al., 1989). Biological monitoring provides a means of indicating absorption or effect of the compound under study. Azinphosmethyl has been a suitable candidate for assessment utilizing biological monitoring because of background information on dermal exposure and dermal absorption in humans and animals under laboratory conditions (Feldmann and Maibach, 1974; Franklin et al. 1981; Franklin et al. 1986). Franklin and co-workers reported a strong linear correlation between urinary alkyl-phosphate levels and both dermal doses of azinphosmethyl in rats (1986) and amount of pesticide sprayed for orchard applicators (1981). The assessment of azinphosmethyl exposure via biological monitoring has been successful in previous studies (Schneider et al. 1990; McCurdy et al. 1992; and Spencer et al. 1992).

MATERIALS AND METHODS

Orchard workers were monitored for exposure to azinphosmethyl residues while picking peaches for processing in Sutter County, California. Sampling consisted of; dermal dosimeters, 24 hour urine collections, and blood draws for ChE effects. Table I includes a study outline and summary of the monitoring schedule. Orchards were treated once with azinphosmethyl (Guthion® 50WP) at the rate of 1.5 lb. active ingredient in 100 gallons of water per acre. Trees being harvested range from six to twenty years old. The younger trees had a much denser foliage and more of the fruit was obscured within the foliage. The older trees had a very open canopy. The sequential dermal and urinary monitoring took place while the workers were picking in the younger trees. The last blood draw and urine collection took place when the workers were in the older trees at the end of the season The crew was Spanish speaking and an interpreter explained the procedures and solicited the workers' voluntary cooperation. Workers agreeing to participate gave written informed consent. The pickers were male and the sorters were male and female. The five female sorters participated in all blood draws. Some workers included with the sorters performed additional tasks including fruit hauling and supervising. The sorters were considered to have had minimal exposure to azinphosmethyl and were used as a control group for the pickers. The sorters live in the area and they do not work where exposure to organophosphates would occur before the start of the harvest season. The sorters go through the fruit in the field contained in the bins removing culls or fruit that is to green. They have minimal contact with tree foliage occasionally picking off a few fruit that may have been left behind by one of the harvesters. The typical work

attire consisted of a long-sleeved buttoned shirt worn over a short-sleeved T-shirt, long pants, shoes, socks and a hat. Peach harvesting took place from mid-July to early September, spanning about six weeks. Workdays were approximately 8 hours.

Table I

Summary of Study Outline

		Number of Workers Measured		
Study Date	Days Post-Application	Dermal	24 hour voids[1]	ChE
8/12/91				33[2]
8/19/91	51	15		
8/20/91	52	13	33	
8/21/91	53	13	34	
8/22/91	54		34	
8/23/91	55		34	33
8/26/91	58			24
9/5/91	68			
9/6/91	69		30	

[1]24 hour voids include the previous day and are collected before the workday begins
[2]baseline, pre-exposure
Dislodgeable foliar residue samples were taken on August 19-23, 27, 29, 30 and September 3-5.

Picking began on August 1 in untreated fields. Workers were picking in treated fields from August 19 through the 22, August 27 to 29 and September 3 to 6. They worked in untreated fields from August 23 to 26 and August 30 to September 2.

Dislodgeable Foliar Residues

The orchards were sampled for DFR using the methods of Gunther et al. (1973). Samples were taken from 10 trees in 3-5 locations in treated orchards, at a height of 5-6 feet and consisted of forty leaf disks, 2.54 centimeters in diameter, cut with a leaf punch. Sample jars were sealed with aluminum foil, capped and kept on ice or under refrigeration until extraction.

Dermal Monitoring

Harvester dermal exposure monitoring was conducted for the entire workday. Hand residue samples were obtained from the peach harvesters by having the worker wash their hands. Each worker washed his hands in a one-gallon plastic bag for two minutes containing 500 mL of 1% sodium dioctyl sulfosuccinate. Face and neck residues were obtained by wiping these regions with two pre-moistened disposable wipes (Chubs®) which were combined for analysis. Wipes were stored in four-ounce glass jars and hand wash solution in 0.5-liter Nalgene bottles. Each worker was given a new, 100% cotton, long-sleeved white knit shirt each monitoring day. They wore the shirts next to the skin under a regular cotton work shirt. The shirts covered the hip region and were tucked into the workers' trousers. At the end of the monitoring period the shirts were stored in

separate, sealed one-gallon plastic bags with a track seal. All dermal dosimeter samples were frozen until extraction. As a check on the effects of dermal monitoring and urinary metabolite excretion levels not all the field workers participated in the dermal exposure portion of the study. Comparisons between the two groups urinary metabolite levels were made.

Sample Analysis

Dermal samples and DFR were analyzed by California Department of Food and Agriculture (CDFA) Chemistry Laboratory Services, Sacramento. Leaf discs were shaken three times with 50 mL 0.05% sodium dioctyl sulfosuccinate solution which was then back extracted three times using 50 mL ethyl acetate. The organic extract was then dried by the addition of anhydrous sodium sulfate (Gunther et al. 1973). After volume reduction the samples were analyzed by gas liquid chromatography. Hand washes were extracted using ethyl acetate, dried with anhydrous sodium sulfate and diluted as necessary for analysis. Shirts, and wipes were extracted and analyzed similarly. Azinphosmethyl was analyzed on a Hewlett-Packard 5880A chromatograph equipped with a phosphorus detector. The chromatographic conditions were: column, 10m x 0.53 mm 50% phenyl methyl silicone; carrier gas (He), 20 mL/min; H_2, 4 mL/min; air, 90 mL/min; injector and detector temperature, 250^o C; oven temperature, 240^o C, isothermal. Using these conditions, the retention time was 6.00 minutes for azinphosmethyl and 4.89 minutes for azinphosmethyl oxon. Minimum detectable levels for azinphosmethyl in micrograms per sample were 5, 1, 1 and 0.25, for the undershirts, wipes, hand washes, and dislodgeable foliar residues, respectively. The corresponding minimum detectable levels for the oxon were 10, 1, 2 and 0.5.

Cholinesterase Monitoring

Blood draws for ChE levels in the volunteers were performed by a phlebotomist on the three sampling dates specified in Table I. Workers were considered to be in one of two groups, the exposed (harvesters) and the unexposed or minimally exposed group (sorters). Plasma and RBC ChE activities were determined using the method of Ellman et al. (1961). Two 5-mL blood aliquots were drawn from each worker at each sampling period. The phlebotomist transported one set of tubes in a cooler containing Blue Ice® to Laboratory 1. The second set of tubes were iced as the samples were drawn and transported by study staff to Laboratory 2. Transportation time was about 45 minutes. Results for Laboratory 1 are reported in international enzyme units per liter (U/L), defined as the activity of enzyme which converts 1 µmole/L of substrate in one minute at standard conditions. Laboratory 2 units are µmoles/minute/mL.

Additionally, a finger prick sample was taken at the time of the last two blood draws and analyzed in the field by the erythrocyte method of Magnotti et al. (1987 and 1988) using the Test Mate™ OP Kit. This kit uses an Ellman-like spectrophotometric method adapted for field studies. Procedural modifications were: (1) automatic micropipettes were used to add the 120 µl buffer and 160 µl distilled water; and (2) a micropipette was used to transfer the dissolved ChE reagent to the spectrophotometer cuvette. Results were automatically temperature adjusted and electronically

displayed for hemoglobin-adjusted ChE (ChE divided by hemoglobin = IU/g hemoglobin, where IU are international units).

Urine Monitoring

Each worker was provided with one-liter polyethylene urine collection bottles as needed each day. Workers were instructed to collect all urine for a 24-hour period that began with the start of the work day and ended after the next mornings void. At the end of every 24 hours the volumes were recorded and a 100-mL aliquot was stored in a 250-mL polyethylene bottle. Samples were stored and shipped frozen to the Pacific Toxicology Laboratories (Los Angeles, California), where analyses for dimethyldithiophosphates (DMDTP), dimethylphosphates (DMP) and dimethylthiophosphates (DMTP) measurements were completed using the method of Takade et al. (1979). Creatinine measurements were used to assess the completeness of urine samples and adjust results of dialkylphosphates to mg/g creatinine. Creatinine was measured by an alkaline picrate method performed on a Beckman CX5 automated analyzer.

Data Analysis

DFR results for azinphosmethyl and azinphosmethyl oxon were summed for each study day. Individual daily dermal exposures were calculated by summing the contribution of the thion and oxon for each dermal medium. Daily means and their standard errors are reported.

Continuous variables were analyzed using Pearson correlation coefficients and T-tests. For urinary metabolites and ChE measurements nonparametric tests and measures (Wilcoxon rank sum, Wilcoxon signed rank, and Spearman correlation coefficient) were calculated in addition to the parametric ones; there were no differences, and only parametric results are reported.

Multivariate analyses were used for analyzing cross-sectional comparisons of ChE levels between exposed harvesters and nonexposed sorters, while simultaneously considering longitudinal changes in ChE over time in both groups. These analyses were conducted using SAS procedure (PROC MIXED), available in newer versions (6.07 or 6.08). PROC MIXED as used here is analogous to the SAS PROC GLM multivariate analyses using the REPEATED feature, although PROC MIXED is more flexible. These analyses took into account the correlation between repeat measurements over time on the same person (an exchangeable correlation matrix was assumed). Only fixed effects were considered. PROC MIXED uses maximum likelihood estimation assuming multivariate normal data, an assumption reasonably well met for these data. However, large sample size assumptions for maximum likelihood estimates may not be fully justified in these data given the relatively limited sample size.

RESULTS

Dislodgeable Foliar Residues (DFR)

DFR values for azinphosmethyl ranged from 0.82-1.72 $\mu g/cm^2$ over the three week study period. Azinphosmethyl levels did not vary significantly during the study, with means of 1.34 $\pm$ 0.04 $\mu g/cm^2$ (n=19), 1.18 $\pm$ 0.10 $/cm^2$ (n=6), and 1.36 $\pm$ 0.03 $\mu g/cm^2$ (n=6) for weeks one, two, and three, respectively. Oxon levels were never above the detection limit of 0.01 $\mu g/cm^2$. Residue levels for the three days of dermal monitoring ranged from 1.1-1.7 $\mu g/cm^2$ and were not significantly different (p=0.05).

Dermal Exposure (DE)

The mean daily DE for the three monitoring days was 32 $\pm$ 1.6 mg (n=41) and ranged from 17.9-60.5 mg per day. Mean results were similar for each day with levels of 31.2 $\pm$ 1.3 mg, (n=15); 35.6 $\pm$ 3.2 mg, (n=13); and 31.1 $\pm$ 3.2 mg, (n=13) for August 19, 20 and 21, respectively. The long-sleeved undershirts, the hands, and the face/neck wipes were found to have accounted for 82%, 16%, and 2% of the total body exposure, respectively. Oxon levels were detected on all sampling media and ranged from 0.6-3.7 mg on the shirts, 0.1-0.4 mg on the hands and 0.002-0.05 mg for the face/neck wipes. The oxon residues accounted for 6% of the dermal exposure. Dermal exposure on day one correlated with total metabolites (DMP + DMTP) collected the following morning ($r=0.58$, $p=0.04$); total metabolites collected after 48 hours were less well correlated ($r=0.47$, $p=.08$). Other comparisons of dermal exposure to urinary metabolites had associated p values >0.10. There was no difference in urinary metabolite levels between those pickers monitored for dermal exposure and pickers providing only 24 hour voids.

Cholinesterase Monitoring

Figures 1 and 2 show the results for RBC and plasma ChE for both exposed (harvesters) and nonexposed (sorters), for both labs (each Lab and its units are indicated by left and right hand vertical axis, note that the units of the two labs are not the same). For RBC, harvesters are lower than sorters for the two post-exposure blood draws, and harvesters but not sorters show a decrease over time after exposure begins. Plasma ChE shows little difference between exposure groups, but both groups show a downward shift in comparison to their baseline values. The shift in plasma ChE values suggests the occurrence of laboratory drift (Aitio 1984).

Figure 1
RBC Cholinesterase

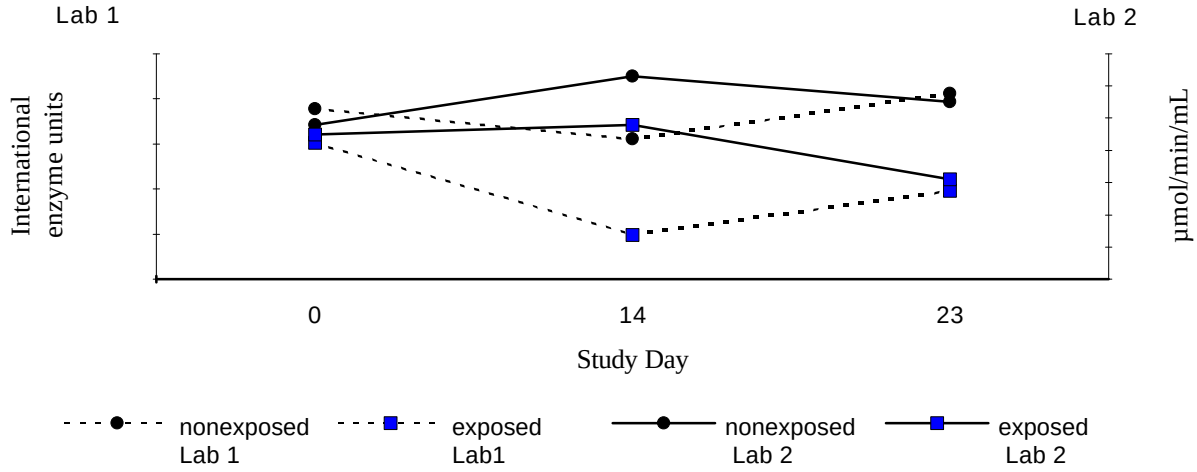
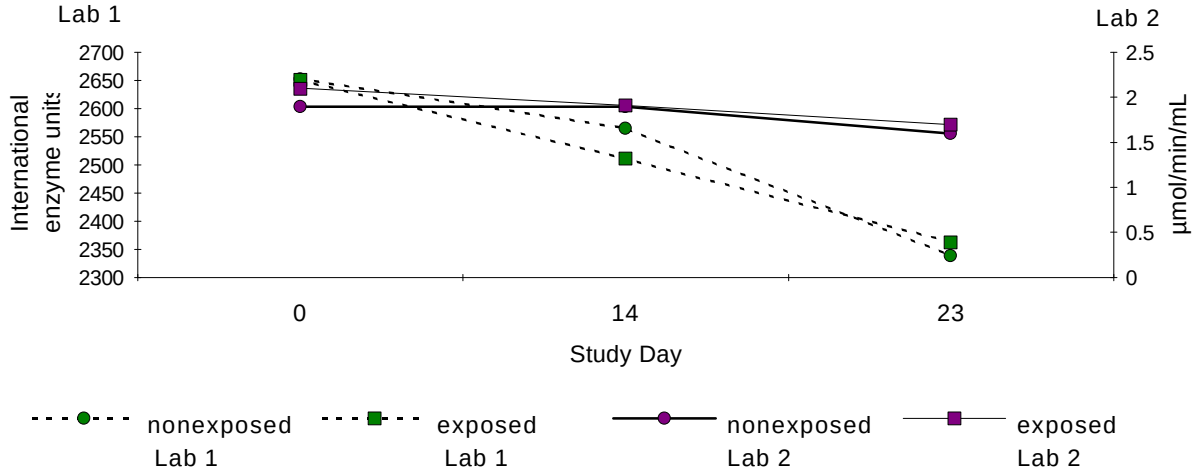


Figure 2
Plasma Cholinesterase



Means for plasma and RBC ChE for harvesters (exposed) and sorters (no exposure or minimally exposed workers) are given in Table II, as well as p-values for t-tests comparing harvesters to sorters at each test date. For laboratories 1 and 2 on August 26 and September 5 t-tests compare the means in each group after subtracting off the baseline value for each individual. There were no significant differences in plasma ChE between exposed and nonexposed at any testing date. The harvesters showed lower RBC (but not plasma) ChE compared to the nonexposed sorters after exposure, but not at baseline prior to exposure. No symptoms of organophosphate poisoning were reported by any of the workers.

Table II
Mean ChE results for harvesters (hvst) and sorters (sort) at each
test date and the corresponding p-values from their t-tests comparisons

	Day 0, 8/12	Day 14, 8/26	Day 23, 9/5
Analysis/Lab/group*	mean & s.e. (n)	mean & s.e. (n)	mean & s.e. (n)
Plasma Lab1 sort	2653 ± 203 (9)	2565 ± 208 (9)	2339 ± 276 (6)
Plasma Lab1 hvst	2651 ± 61 (24)	2511 ± 69 (24)	2363 ± 74 (17)
	(p=0.99)	(p=0.49)	(p=0.17)
Plasma Lab2 sort	1.9 ±0.2 (10)	1.9 ± 0.2 (9)	1.6 ± 0.2 (6)
Plasma Lab2 hvst	2.1 ± 0.1 (24)	1.9 ± 0.05 (24)	1.7 ± 0.1 (17)
	(p=0.13)	(p=0.10)	(p=0.51)
RBC Lab1 sort	6893 ± 202 (9)	6553 ± 158 (9)	7062 ± 250 (6)
RBC Lab1 hvst	6515 ± 143 (24)	5495 ± 104 (24)	5983 ± 300 (17)
	(p=0.17)	(p=0.006)	(p=0.008)
RBC Lab2 sort	9.8 ± 0.3 (10)	11.3 ± 0.3 (9)	10.5 ± 0.3 (6)
RBC Lab2 hvst	9.5 ± 0.2 (24)	9.8 ± 0.4 (24)	8.1 ± 0.4(17)
	(p=0.44)	(p=0.001)	(p=0.001)
RBC Kit sort	na	30.4 ± 1.1 (8)	33.4 ± 1.4 (6)
RBC Kit hvst	na	26.8 ± 1.0 (23)	25.7 ± 1.2 (22)
		(p=0.056)	(p=0.003)

**p-values for labs 1 and 2 for cross-sectional comparisons of exposed vs nonexposed at day 14 and day 23 are for t-tests comparing mean levels for each group after subtracting off the baseline value for each individual. No baseline was available for the Kit.

*Sorters were exposed minimally and served as a nonexposed comparison to exposed harvesters.

RBC is red blood cell values.

Lab1 units are U/L of red blood cells.

Lab2—units are μmol/min/mL

Kit (Test Mate OP Kit)—units are U/g hemoglobin.

Longitudinal analyses over time (mean differences and p-values for t-tests) for the RBC ChE and plasma ChE data are presented in Table III. For the exposed group three of four comparisons (2 post-exposure tests at two labs) for RBC ChE showed a decrease in RBC values post exposure versus baseline pre-exposure values (two were significant). The harvesters plasma ChE showed a significant decrease over time for all four comparisons. For the nonexposed RBC ChE increased in three of four comparisons while all the plasma ChE values decreased but not significantly. The Kit data could not be evaluated longitudinally for lack of a baseline. No pattern of decreases was observed for the nonexposed.

Multivariate analyses of the RBC data showed no effect of age, weight, height, or sex. A cell mean model (ANOVA) showed a significant difference of the average of the two post-exposure RBC ChE means, with exposed lower than nonexposed, for both labs (p=0.0007 for Lab 1 and p=0.0002 for

Lab 2).

Table III
Mean differences and paired t-tests for post-exposure
versus pre-exposure for RBC ChE and plasma ChE

			Plasma ChE		RBC ChE		
Task	Dates	Lab	$\bar{d}$	p =	$\bar{d}$	p =	N
Sorters*	8/26 vs 8/12	Lab1	-89	0.19	-340	0.07	9
		Lab2	-0.08	0.20	1.6	0.0001	
	9/5 vs 8/12	Lab1	-208	0.04	410	0.02	6
		Lab2	-0.35	0.02	0.8	0.08	
Harvesters	8/26 vs 8/12	Lab1	-140	0.0007	-1020	0.0001	24
		Lab2	-0.20	0.0003	0.38	0.13	
	9/5 vs 8/12	Lab1	-335	0.0001	-428	0.12	17
		Lab2	-0.43	0.0001	-1.3	0.0008	

*Sorters were exposed minimally and served as a control for the exposed harvesters.
Lab1 units are U/L of red blood cells.
Lab2—units are μmol/min/mL

When regression lines were fit separately for exposed and nonexposed groups over time (each lab separately), the exposed group showed a significantly negative (downward) slope over time (-0.041 units per day, p=0.003, at Lab 2, and -32.87 units per day , p=0.0004, at Lab 1). Although expressed in different units, these downward slopes were similar in magnitude. In contrast the nonexposed group showed a flat (Lab 1) or upward slope (Lab 2) over time. For both labs the slopes of the regression lines for exposed and nonexposed differed significantly. Intercepts at baseline did not differ for either lab.

Table IV presents correlation coefficients and significance levels between RBC methods by date for the exposed group. All correlations were highly significant for all test days.

Table IV
Correlation coefficients between red blood cell ChE tests for exposed group

RBC Laboratory comparisons	r =	p =	n
8/12 Lab2 vs. Lab1	0.63	0.0010*	24
8/26 Lab2 vs. Lab1	0.86	0.0001*	24
9/5 Lab2 vs. Lab1	0.75	0.0005*	17
8/26 Lab1 vs. Kit	0.66	0.0005*	23
9/5 Lab1 vs. Kit	0.88	0.0001*	17
8/26 Lab2 vs. Kit	0.65	0.0008*	23
9/5 Lab2 vs. Kit	0.92	0.0001*	17

*significant at $p < 0.01$

Urinary monitoring

The results of the analyses for the presence of DMP and DMTP are reported in Table V. Values for DMDTP are not reported because they were not detected in 90% of the samples. Mean creatinine values were 1.4 g/L with 90% of the 24 hour urine collection having volumes greater than 700 mL. Both sorters and harvesters generally showed increasing levels of metabolite excretion over sequential monitoring days (8/20-8/23). Metabolite excretion for sorters averaged 4% of that found for the harvesters. While both 8/22 and 9/6 represent a third sequential exposure day, the urinary metabolite means for 9/6 are 30-40% of those collected the morning of 8/23. Overall means of DMP and of DMTP and their associated standard errors for the five urine monitoring days using creatinine-adjusted (mg/g creatinine) values were 1.8 $\pm$ 0.17 and 2.0 $\pm$ 0.14, respectively, for the harvesters (n=119); and 0.06 $\pm$ 0.009 and 0.08 $\pm$ 0.01, respectively, for the sorters, (n=41).

Table V
urinary dialkylphosphates mg/g creatinine
(mean and standard error)

Group	Day	N	DMP	DMTP
sorters	8/20	10	0.044 $\pm$ 0.088	0.066 $\pm$ 0.015
sorters	8/21	10	0.035 $\pm$ 0.007	0.066 $\pm$ 0.017
sorters	8/22	10	0.077 $\pm$ 0.022	0.136 $\pm$ 0.31
sorters	8/23	10	0.108 $\pm$ 0.023	0.084 $\pm$ 0.013
sorters	9/6	5	0.040 $\pm$ 0.006	0.035 $\pm$ 0.007
harvesters	8/20	24	1.5 $\pm$ 0.21	1.8 $\pm$ 0.22
harvesters	8/21	23	1.2 $\pm$ 0.35	1.4 $\pm$ 0.032
harvesters	8/22	24	2.1 $\pm$ 0.41	2.6$\pm$ 0.37
harvesters	8/23	24	3.1 $\pm$ 0.53	3.1 $\pm$ 0.38
harvesters	9/6	24	0.90 $\pm$ 0.12	1.2 $\pm$ 0.14

Higher levels of urinary phosphates indicate higher exposure, while lower levels of cholinesterase also indicate higher exposure. To assess the correlation between urinary phosphates and cholinesterase among the exposed group we averaged the five urinary phosphate levels (August 20, 21, 22, 23 and September 6), and then correlated these means with the average post-exposure (August 25 and September 5) red blood cell and plasma cholinesterase (after subtraction off the baseline value). The results (Table 6) indicate that red blood cell cholinesterase was significantly inversely correlated with urinary phosphates at both laboratories, for each of the two urinary phosphates (DMP and DMTP). Plasma cholinesterase was inversely correlated as well, but the correlation was not statistically significant. While the inverse correlation between average urinary phosphate and average post-exposure plasma cholinesterase was not significant, on the one occasion when both urine and cholinesterase data were obtained at approximately the same time (September 5 cholinesterase, and September 6 urine), there was a significant inverse correlation at Lab 1, although not at Lab 2 (both plasma cholinesterase and urinary phosphates should reflect exposure during the previous 1-2 days).

Table VI
Correlation coefficients for average post exposure red blood cell and plasma cholinesterase (after subtracting baseline) and average urinary dimethylphosphates adjusted for creatinine (exposed group only).

Laboratory	N	DMP	DMTP
Lab1 RBC	17	-0.58 (p=0.01*)	-0.65 (p=0.01*)
Lab2 RBC	17	-0.47 (p=0.06)	-0.56 (p=0.05*)
Lab1 Plasma	17	-0.21 (p=0.21)	-0.37 (p=0.15)
Lab2 Plasma	17	-0.35 (p=0.17)	-0.29 (p=0.27)

*significant at p = 0.01

DISCUSSION

DFR levels were twice those found during the two previous years at this location in 1989 (0.59 μg/cm^2) and 1990 (0.46 μg/cm$^{2)}$ (Spencer et al. 1993) while application rates were unchanged over the three years. This is similar to the observations observed by Kraus et al. (1977) and Richards et al. (1978) where DFR levels varied from 0.43 vs. 2.2 μg/cm^2 14 days post application at the same locale over two consecutive years. DFR samples were not taken at the time of application but the half life for azinphosmethyl at this locale was previously calculated to be 32 ± 7 days (Spencer et al. 1993). Knaak et al. 1982 calculated a safe level for azinphosmethyl on foliage of 1.6 μg/cm^2 using dermal dose-ChE response curves, developed from animal models, and field exposure data. Knaak's method took into account the higher toxicity levels of the oxon residues which were not detected in this study. DFR levels remained unchanged over the study period and any trend reflecting changes in dermal exposure or urinary metabolite levels could not be evaluated in its relationship to foliage residues.

Dermal exposure measurements of 32 mg were similarly twice the levels measured the previous two years at 15.5 mg in 1989 and 13 mg in 1990 (Spencer et al. 1992). The contribution of the dermal exposure measured by long-sleeved shirts was greater than in the two previous years, (82% vs. 66% & 57% in 1989-90) but was similar to the exposure distribution measured at three other locations (Spencer et al. 1993). The cumulative dermal exposure for the three days of dermal monitoring was 98.4 mg. The cumulative urinary equivalents (the ratio of the molecular weight of azinphosmethyl to the molecular weight of the various metabolites) was 37.8 mg for the four consecutive days that correspond to the dermal monitoring. An indirect estimate of 28% dermal absorption was calculated by dividing the urinary equivalents by the sum of dermal exposure and urinary equivalents. This estimate is similar to previous estimates for dermal absorption of azinphosmethyl by this Branch (17%-35%, Spencer et al. 1993) and is within the range of 16-42%,

depending on regional variation in absorption, found in laboratory studies conducted by Maibach et al.(1971) and Franklin et al. (1981).

Feldman and Maibach (1974) showed urinary metabolite excretion for azinphosmethyl to be 5.5, 5, 3, 1.4 and 1%, respectively, for days 1-5 following a single topical application. Our study showed an increase in urinary phosphates levels for consecutive exposure days due to the additive effects of previous exposure days. This additive effect may account for the poor correlations that were seen between dermal exposure and and urinary metabolites after the first exposure day. Dermal exposure is comparatively easier to monitor and in some situations one might prefer to use dermal exposure as a predictor of absorbed dose in humans. Dialkylphosphate results for September 5 to 6 were lower than expected since harvesters had been exposed for three consecutive days to DFR levels similar to those of August 26. This decline could be related to differences in growth habit that were observed between tree varieties. The trees harvested earlier in the season had denser foliage and the later variety grew more vase-like with an open canopy allowing the worker to contact less foliage during picking.

Urinary phosphates are an indicator of exposure. Since exposure conditions are likely to be relatively uniform for all workers on a given day, urinary phosphate levels on a given day may vary principally due to different work practices by different workers, although unique absorption and excretion biology may also account for some inter-individual variability. Urinary phosphates were measured on five separate days, and pair-wise correlations for exposed workers between these different days were consistently highly positive and highly significant, probably indicating that some workers consistently engage in work practices which led to higher exposures than other workers. When we averaged all five urine measurements taken during the entire exposure period and compared them to the average of the two post-exposure cholinesterase measurements (after subtracting off baseline cholinesterase), we found a significant inverse correlation at both labs for red blood cell cholinesterase, but not for plasma cholinesterase. This finding is in accord with our findings for cholinesterase, which indicate that pesticide exposure among these workers resulted in some measurable inhibition of red blood cell cholinesterase, but no plasma cholinesterase inhibition. In a previous study (McCurdy et al. 1992) where monitoring was conducted under similar circumstances the correlation with urinary phosphates was poor for both plasma and RBC values but DFR values were half those in this study. Richards et al. (1978) studied workers thinning peaches and correlated dialkylphosphate metabolites with percent decline in RBC ChE ($r = -0.581$ and -0.598 for DMP and DMTP, respectively) where azinphosmethyl DFR levels were 2.2 $\mu g/cm^2$, results similar to ours.

Our findings for RBC ChE indicated that exposed workers experienced a 10-20% decrease over the 3 week exposure period, while the nonexposed workers did not. Plasma ChE was not affected. These findings are consistent with the literature showing a RBC but not plasma effect of azinphosmethyl (Richards et al. 1978), as is typical for methylated organophosphates. Biologically

it is plausible that workers exposed at a relatively constant dose would exhibit constantly decreasing RBC ChE levels over time (as opposed to an initial inhibition which remains constant over the exposure period). However, this depends on a complicated interaction between the strength of the OP cholinesterase bond, the regeneration rate of red cells, and the level of dose. Under the assumption of a constantly increasing inhibition, our data indicate that at these dose levels for azinphosmethyl it would take 3-4 months before 50% inhibition occurred (100 days based on Lab 1 data, 120 days based on Lab 2). Under California law Code of Regulations Title 3, section 6728e, pesticide handlers (mixer/loader/applicators) are removed from further exposure when RBC ChE levels fall to 70% of baseline. Under the assumption of constantly increasing inhibition it would take 57 days to reach this level based on Lab 1 data and 72 days based on Lab 2 data.

The Test-Mate OP Kit was easy to use in the field and the workers preferred the finger prick to the drawing of a venous blood sample. McConnell et al. (1992) found that the kit performed well in the field with interindividual variability to be 7.4% for a nonexposed group for Hemoglobin (Hgb) adjusted erythrocyte ChE. In this study the coefficient of variation was approximately 10% for the nonexposed Hgb adjusted values. Although there were positive correlations with the other two laboratories and the Kit, the lack of a "gold standard" for ChE prevents any conclusions regarding the relative validity of the kit and laboratory for ChE measurements.

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